Applying Aviation Training Techniques in the IT Classroom

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ABSTRACT

Aviation training is a rigorous process requiring the student pilot to learn the theoretical underpinnings of multiple subjects, risk management and decision making under stress, and, of course, the skills necessary to fly a plane. The educational process is rooted in learning theory, but it utilizes several approaches more fully than in typical academic classrooms resulting in a significantly greater level of engagement.

This paper documents the results of a pilot study to apply three of these approaches in an information technology programming course—the Master/Apprentice approach, a focus on task mastery vs. time on task, and shared responsibility for achieving goals. While these three approaches were implemented to a limited degree during the pilot, the successful results suggest a more complete implementation of these approaches which is also outlined in this paper.

CCS CONCEPTS

• Social and professional topics~Professional topics~Computing education~Computing education programs~Information technology education • Applied computing~Education~Interactive learning environments • Applied computing~Education~Collaborative learning

KEYWORDS

Master, Apprentice, Time for Mastery, Expectations, Collaboration, Engagement

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1 Background

While academicians are always in a constant state of learning, the vast majority of our new knowledge is incremental to what we already know. This is very different from our undergraduate (and sometimes graduate) students who are often learning new, radically different knowledge in our classrooms. For those of us who have been practicing for many years, it is easy to forget what it was like to learn something very new. It is also difficult for many of us to remember what it was like to be a 20-year-old wanting to learn new skills, but at the same time very concerned about proving himself/herself, graduating, and getting a job.

In 2018, the author embarked on a lifelong ambition and began training for a private pilot's license. Like our students, this represented new, radically different knowledge. There were the electrical, pneumatic, and fuel systems of the aircraft to learn in detail, there were the theories of meteorology and aerodynamics to learn, and there were volumes of federal regulations to memorize. And, of course, there was the need to learn to fly the plane! The author found himself surrounded by an overwhelming mountain of information, none of which seemed to fit together, and could immediately sympathize with many of our students.

1.1 Aviation Training

All aviation instructors are Certified Flight Instructors (CFI). This means that not only are they accomplished pilots, but they have also received training and passed a test regarding educational theory. The primary reference for this is the Aviation Instructor's Handbook. [4] The handbook and accompanying course cover learning theory (including the work of Dewey, Piaget, Bloom, et al.), instructional methodologies (lecture, problem-based learning, demonstration-performance, assessment, etc.), human-behavior, memory, and many other topics related to the education process.

The actual subject matter for the student to master is also wide-ranging including aircraft systems and construction, human physiology and psychology, aerodynamics and weather systems, and the National Airspace System and associated "rules of the road".

Training is divided into ground school where students learn about the subject matter, and flight time where the students practice what they have learned. The regulations [7] allow for the ground school to be taught either in a traditional classroom setting with an instructor or in a self-paced, self-taught mode using commercially available lessons but always under the supervision of an instructor.

Flight time is always done under the supervision of an instructor. Here, too, the regulations permit this instruction to take place in a very specific manner or a more free-form manner [5]. However, it is always done one-on-one in a master-apprentice style. A typical lesson consists of the following steps:

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1. Student reviews material before class
2. Student and CFI conduct preflight briefing (verification/clarification of understanding)
3. First portion of flight reinforces past skills
4. CFI conducts a demo of new maneuvers
5. Student attempts new maneuvers with CFI guidance
6. Student and CFI conduct post-flight debrief
7. Student is given assignment for next lesson (review this material and/or introduce new material)

Throughout the ground school and the flight time, a very strong emphasis is placed on Aeronautical Decision Making (ADM)—evaluating the situation and choosing the safest means to deal with it. This might mean knowing how to deal with the loss of an engine or simply choosing not to fly if the conditions are marginal (e.g., a weather front with associated high winds is approaching the area).

1.2 Engagement

Aviation training is difficult. While there are no definitive studies, it is generally reported [1, 9] that fewer than half of all student pilots complete their training. Yet, those who do complete their training will speak fondly of it and often have a lifelong relationship with their instructor, seeking additional training from the same instructor as the student becomes more immersed in the field.

This engagement has to first come from the student with his/her desire to learn, but there are several key factors in the standard aviation training approach that encourage that high level of engagement. Because the author was not only successful in the pursuit of his license but also enjoyed and continues to enjoy this high level of engagement, an attempt was made to bring some of these different educational approaches into the classroom.

These high engagement approaches include:

1. The Master/Apprentice approach that supports the idea that the instructor and the student are working together to achieve the student's success
2. A very specific Transparency of Expectations that allows the student to know exactly what is required of him/her.
3. Allowing sufficient Time for Mastery places emphasis on learning the material rather than achieving a grade.

1.3 Assessment

Assessment of the student pilot's progress is conducted in several forms. Ground school lectures, whether delivered in a classroom setting or via a self-study course, are always followed by a short quiz to ensure the student has grasped the important concepts. The quizzes are intended to be formative so the student may retake them as often as he/she likes.

When the instructor believes the student is ready for his/her first solo, a solo readiness test is administered. This test is relatively short and simply confirms, again in a formative matter, that the student has all necessary facts and figures (e.g., critical speeds known as v-speeds) memorized.

The majority of assessment and accompanying feedback throughout the training is informal and ad hoc in nature. The CFI is always working with the student to overcome gaps in skills and knowledge.

The critical tests come at the end of the student's training. This is a true summative evaluation. In order to get his/her pilot's certificate, the student must take three tests. At the end of the ground school, the student will sit for the first test, but only after his/her instructor has signed off that the student is ready. This is a 60-question standardized Knowledge Exam administered by the federal government that tests knowledge of facts and formulae. The student needs to pass this with at least a 70 in order to proceed to the next test.

That next test is an up to 2-hour oral exam by a federal examiner, not the CFI, who will ask about the items the student got wrong on the Knowledge Test and then focus on the student's understanding and decision making. The student will be presented with several no-win scenarios; failure to demonstrate solid reasoning will result in failure. If the student passes that exam to the examiner's satisfaction, he/she then gets to take the practical test with the examiner.

In the practical test, which can take up to three hours, there will be additional examination of the student's decision making, but the primary focus will be on the student's demonstration of all the tasks in the Airman Certification Standards (ACS) [3] within the specified limits. Failure to complete any of the tasks within the specified limits results in an overall failure. However, following certified additional instruction from the CFI, the student may re-try the tasks he/she failed.

This is a high-stress situation, but just like a thesis defense, if the student has listened to their instructor and the instructor believes the student is ready, it should end well.

2 Study Design

These high engagement ideas are not new. For centuries, we have practiced the master/apprentice model with our PhD students. In his 1974 *Time and Learning* article, Bloom described the idea of Mastery Learning, referencing a great deal of previous work on the subject [2]. A decade later, Slavin presented an analysis of several studies on Mastery Learning [8].

Similarly, a great deal of work has been done on competency-based learning (CBL). For example, Lee and Pant, in addition to describing prior work, present a study [6] in which they used CBL techniques quite successfully.

The difficulty arises when trying to apply these ideas in our typical classroom. How do we use a master/apprentice model when we are trying to teach 30 apprentices at the same time? How do we transparently define expectations for nebulous concepts such as "good, maintainable code"? And how can we allow varying amounts of time to master a topic when we are operating in a fixed-length term?

A graduate-level coding class, Database Connectivity and Access, was chosen as a test case for implementing these approaches. Enrollment in the course is typically 10-20 students, 90% or more are international students, and about 25% are women. Major topics of the course include:

1. The role of the Data Layer in a multi-tiered application
2. How to connect to various databases from various languages
3. How to construct and use various types of data access objects
4. Security considerations (e.g., SQL injection)
5. Performance considerations (e.g., connection pooling)

In the fall semester of the 2020-21 academic year, a pilot study was conducted. During this pilot, these three high engagement approaches were implemented in a limited degree to determine student reaction and satisfaction. Based on student feedback, a more rigorous implementation of these approaches will be implemented in the fall 2021-22 semester.

Due to the pandemic, the pilot implementation was taught in a hybrid fashion. Approximately half of the students attended in-person while the other half were 100% remote. All students were required to watch one or more pre-recorded video lectures each week. Discussion and elaboration of the material was held in the classroom for those students attending in-person and online in group or 1-on-1 sessions for those students attending remotely. The fall 2021-22 course will be taught as a flipped classroom.

2.1 Master/Apprentice Approach

Throughout their education, students often view the student/instructor relationship as a contest between adversaries. Can the student guess what the instructor will have on the test? Will the instructor give the student a good grade? What assignments must the student complete in order to pass the course? What is the minimum grade on the final that is necessary to get a desired grade (e.g., A, B, etc.)? Getting past this attitude and developing a mindset of collaboration is the biggest hurdle in implementing the Master/Apprentice approach, particularly when the contest attitude is simultaneously being reinforced in other courses.

A very concerted effort was made to convince students that the instructor was "on their side". This began with a simple declaration of how the instructor wanted the course to proceed and a description of his experience as a student pilot. This was reinforced throughout the course, but particularly in the first weeks, with a great deal of 1-on-1 interaction. The combination of in-person and remote students aided this. The smaller number of students in the classroom provided a more intimate setting allowing more personal interaction while remote students spent more time in 1-on-1 zoom meetings with the instructor than they typically would in traditional office hours.

This did require significantly more time on the part of the instructor relative to a more traditional and more didactic approach, but it did successfully establish a cooperative relationship between the student and instructor.

2.2 Transparency of Expectations

There are at least two ways to think about Transparency of Expectations. One is a strong sense of what you will gain from the course; i.e., what will you be able to do upon successful completion. A second is how well you must perform in order to be considered competent with a particular skill. While it is quite common to include a list of course topics in a syllabus and sometimes to provide, in advance, a rubric for a specific test, details of skills to be learned and quantifiable indicators of mastery are rarely provided to students. This is also true in most CBL implementations where students may have advance knowledge of required topics, but not necessarily of required level of mastery.

In contrast, the ACS lists every skill and mastery level that a student pilot will be asked to demonstrate. One example of the ACS skill list is shown in Figure 1. There are 37 such skills (the ACS refers to them as Tasks) for a Single-Engine Land pilot certificate.

Task	**A. Steep Turns**
Objective	To determine that the applicant exhibits satisfactory knowledge, risk management, and skills associated with steep turns.
Knowledge	The applicant demonstrates understanding of:
PA.V.A.K1	Purpose of steep turns.
PA.V.A.K2	Aerodynamics associated with steep turns, to include:
PA.V.A.K2a	a. Coordinated and uncoordinated flight
PA.V.A.K2b	b. Overbanking tendencies
PA.V.A.K2c	c. Maneuvering speed, including the impact of weight changes
PA.V.A.K2d	d. Load factor and accelerated stalls
PA.V.A.K2e	e. Rate and radius of turn
Risk Management	The applicant demonstrates the ability to identify, assess and mitigate risks, encompassing:
PA.V.A.R1	Failure to divide attention between airplane control and orientation.
PA.V.A.R2	Collision hazards, to include aircraft and terrain.
PA.V.A.R3	Low altitude maneuvering including stall, spin, or CFIT.
PA.V.A.R4	Distractions, improper task management, loss of situational awareness, or disorientation.
PA.V.A.R5	Failure to maintain coordinated flight.
Skills	The applicant demonstrates the ability to:
PA.V.A.S1	Clear the area.
PA.V.A.S2	Establish the manufacturer's recommended airspeed; or if one is not available, an airspeed not to exceed VA.
PA.V.A.S3	Roll into a coordinated 360° steep turn with approximately a 45° bank.

PA.V.A.S4	Perform the Task in the opposite direction, as specified by evaluator.
PA.V.A.S5	Maintain the entry altitude ±100 feet, airspeed ±10 knots, bank ±5°, and roll out on the entry heading ±10°.

Figure 1: Sample Airman Certification Standards Task

2.2.1 What will you learn?

Many instructors will use the first day of class to discuss or demonstrate the outcome of the course and this course was no different. The first day would include a discussion of the role of the data layer in Amazon or some other web application and then subsequent lessons would take the students through all the steps necessary for a data layer, beginning with a (less-than-thrilling) discussion of drivers, continuing through various statement types, and then the creation and use of data access objects.

For this pilot, the instructor created a library to encapsulate all the "messiness" (e.g., binding values in prepared statements, converting result sets to native data structures) and provided it to the students for the first few weeks of class. This allowed them to first focus on the data access objects themselves, understanding their purpose and proper usage without getting bogged down in the coding details. Then, with a firm understanding of where they were headed, the students began to learn about the coding details and to recreate the instructor-provided library.

2.2.2 How well must you learn it?

The second aspect of Transparency of Expectations, level of competence, was not addressed in any novel way. The students were aware that their test questions would look just like their homework exercises and that they would be graded similarly, the difference being the quality of their code being considered less strongly on the tests. Plans to do much more in this area are described in the Future Work section of the paper.

2.3 Time for Mastery

Typical formal education is time-boxed—students have some fixed number of weeks to learn the specified material. This is additionally constrained within the typical curriculum to spend some fixed amount of time on each topic within the course. A student who does not grasp the topic in the allotted time is required to move onto the next topic without a strong foundation. In contrast, aviation training is not time-boxed. You may prepare for a period of weeks, months, or years. Only when your CFI believes you are ready, may you sit for the final tests. This is more like PhD training than the typical classroom.

For this course, two changes were made in order to allow a more customized time for mastery. First, material was provided in a layered fashion. That is, a particular topic might be covered multiple times during the course, first in its most basic form, then in an intermediate form, and lastly in an advanced form. Secondly, students were allowed and encouraged to correct and resubmit work after initial grading. The hope was that students would take the time they needed to learn the fundamentals and forego the advanced material if time did not permit. Some students did indeed take advantage of this while others proceeded in a more traditional manner, accepting a middling grade and moving on to the next topic.

Such an approach requires a high degree of differentiated teaching and can significantly increase the instructor's workload. However, due to the pandemic the course was taught in a flipped-classroom style with prerecorded videos. This permitted students to work at an adjusted pace without significant additional work for the instructor. A combination of release dates for the lecture material and scheduled tests kept the students on a reasonable pace, but still allowed some flexibility.

3 Results

Both the students and the instructor were pleased with the outcomes of using these adjusted teaching approaches. Final grades were comprised of As and Bs with no failures and no withdrawals. In a post-course survey, 80% of the respondents reported that they liked the teaching style and enjoyed the course a great deal. Students also expressed that they felt they learned a great deal in the course.

All surveyed students stated that they appreciated the opportunity to re-do their work (Time for Mastery), that they felt the tests reflected their preparation (Transparency of Expectations), and that they felt the instructor strongly cared about their success (Master/Apprentice).

In fact, many of the students have approached the instructor to chair their capstone defense committee in much the same manner a pilot goes back to their CFI for additional instruction. Anecdotally, one student scheduled a meeting with the instructor the following semester to describe how what she had learned in the class helped her get a co-op position. Both of these point toward the success of the master/apprentice approach.

4 Future Work

The work done during the fall 2020-21 semester represented a simplified implementation of the three high engagement approaches (Master/Apprentice, Transparency of Expectations, Time for Mastery). Refinements and a deeper application of these approaches are planned for fall 2021-22.

4.1 Master/Apprentice

In the aviation training situation, the master and the apprentice are working together for success on an exam administered by a third party, the federal government. This makes it more natural for the master and the apprentice to work together, as a team, as they aim for satisfying the government-established requirements. In our classrooms, however, the "master" is also the creator of the assessment materials, making this camaraderie between master and apprentice less natural. Nevertheless, in the next version of the course, an attempt will be made to hold out the final exam in a dispassionate, or detached, manner. Emphasis will be placed on working together toward this shared goal of passing the test. Students will receive formative feedback and encouragement on their assignments throughout the semester, but their course grade will depend only on the final tests. It is expected that the formative feedback on assignments, as opposed to summative feedback, along with the practices put in place during the pilot, will all contribute to a spirit of collaboration.

4.2 Transparency of Expectations

Typically, instructors will list course topics in the syllabus and then, prior to a test, provide students with a more detailed list of topics that they need to know. On the test itself, instructors may include an even more detailed rubric listing how many points each subitem is worth, but rarely does an instructor lay this out in the beginning of the course.

In the next version of the course, required skills and an associated level of competence will be fully documented and presented to the students in the beginning of the course and referenced throughout the course. Figure 2, Sample Course Task, shows one such skill.

Task	**A. SQL Vulnerabilities**
Objective	To determine that the student understands the risks and prevention methods for SQL Vulnerabilities.
Knowledge	The student demonstrates understanding of:
	The typical types of SQL Vulnerabilities, including:
	a. Dynamically constructed SQL
	b. Malformed queries
	c. SQL Injection
	How typical SQL Vulnerabilities operate, including:
	a. Dynamically constructed SQL
	b. Malformed queries
	c. SQL Injection
	The importance of guarding against SQL Vulnerabilities.
Skills	The student demonstrates the ability to:
	Use appropriate techniques to guard against typical SQL Vulnerabilities including:
	a. Sanitizing input
	b. Exception handling
	c. Prepared statements
	Write code without exposure to typical SQL Vulnerabilities.

Figure 2: Sample Course Task

4.3 Time for Mastery

A student pilot is not taught everything in the Steep Turn task (Fig. 1) all at once. For example, how and why we "clear the area" is a separate, and early, lesson all by itself. Similarly, the student is not expected to maintain all the specified constraints initially. That comes only after many hours of gaining comfort with the handling of the plane. Additionally, when working on more advanced certificates beyond that of a private pilot (e.g., Commercial pilot or Airline Transport Pilot), many of the same skills are tested, but to tighter tolerances.

We can follow that same model in our efforts to provide more time for mastery. Once the tasks are identified for the course, they will be broken down into lessons in a scaffolding manner so that students can gain confidence with their work yet still have a goal for better performance. Some of the skills and their performance constraints will be deemed essential to the course and students will be required to demonstrate them in order to pass the course. Once a student has done that, they may move on to other tasks that have been deemed a higher level performance; successfully demonstrating these tasks will result in a higher grade in the course. An example of this scaffolding might be the student first demonstrating the ability to connect to a local MySQL database, then demonstrating the ability to connect to a variety of remote DBMS databases, and finally, perhaps, demonstrating the ability to manage multiple connections at once.

This approach introduces a degree of self-pacing as well as a degree of ownership. The students will still need guidance and encouragement to ensure they do not fall behind or simply wait until the end of the course to begin their work. Goals and checkpoints will be introduced to help the students maintain a reasonable pace.

4.4 Overall Course Design

To accomplish these changes, the course will be designed in the following manner:

1. A flipped classroom approach is employed. Students will be responsible for gathering information from multiple sources before coming to class. Class time will be used for hands-on work, clarification, and elaboration.
2. Video lectures will be accompanied by auto-graded quizzes so that students can perform self-checks.
3. Regular exercises (based on 1 or more video lectures) will be assigned. Student submissions will be reviewed and returned with formative feedback. Feedback will be discussed in class with the instructor and with peers.
4. As the semester progresses, lectures will cover more sophisticated considerations of previously discussed topics.
5. Periodic checkpoints to assess progress and provide confidence (similar to student pilot solos) will be assigned and reviewed.
6. Final exam will be given during penultimate week of class, graded, and returned with summative feedback. Students will have the following week to clarify any deficiencies and gain additional understanding.
7. Re-test of any deficiencies identified on final exam will occur during finals week.

5 Conclusion

Both formal and informal feedback from the students in the pilot study indicates that they very much enjoyed the idea of collaborative (Master/Apprentice) learning aimed at a welldefined goal (Transparency) and the ability to revisit and refine earlier work (Mastery). The demonstration of their willingness to take on more responsibility for their learning was shown to be good for most of the students in the course, but not universal. Future work will focus on this and also more fully implementing these high-level engagement approaches.

What remains to be seen from the future work is how well these approaches scale, both in terms of instructor workload and student engagement.

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